The contrasting impacts of nutrient loading and zooplankton grazing on the growth and toxicity of cyanobacteria blooms in a eutrophic New York lake

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Introduction

Cyanobacteria blooms are common in poorly flushed, eutrophic freshwater environments and have been specifically linked to phosphorus loading in many lake ecosystems. However, less is known about how the toxicity of wild populations is effected by nutrients. Grazing by some zooplankton can be disrupted by cyanobacteria, but little is known regarding how specific toxins or cellular toxin synthesis by wild cyanobacteria effects zooplankton grazing. While many downstate NY lakes experience summer cyanobacteria blooms, nothing is known about the toxicity of cyanobacteria in this region nor the factors which promote bloom growth and / or toxicity.

Hypotheses

Cyanobacteria blooms in some downstate NY lakes are toxic and are promoted by phosphorus loading and an abatement of zooplankton grazing.

Methods

During 2003 and 2004, we investigated the dynamics and toxicity of cyanobacteria populations in Lake Agawam, a eutrophic lake on Long Island, NY. Concurrently, experiments were conducted to evaluate the contrasting effects of zooplankton (mesozooplankton and microzooplankton) grazing and nutrient loading on the abundance and toxin content of cyanobacteria populations. Molecular techniques were used to assay for toxin (microcystin) synthetase gene presence and expression.

Results

Lake Agawam hosted dense blooms of *Microcystis* spp. and *Anabaena* spp. with cell densities exceeding 10^5 cells ml^{-1} and chlorophyll *a* concentrations up to 200 µg L^{-1}. Microcystin was present in all samples collected during both years (up to 50 µg L^{-1}; May-Nov; n = 130) while anatoxin-a was detected during late summer only (~1 µg L^{-1}). Polymerase chain reaction (PCR) analysis targeting the microcystin synthetase gene (mcyE) indicated that *Microcystis* spp., but not *Anabaena* spp., was responsible for microcystin production in this system. Moreover, reverse transcriptase PCR indicated the *Microcystis* population strongly expressed the mcyE gene during summer months, but rarely expressed the gene during the fall when in situ populations and microcystin levels in the lake declined. During summer, when there was strong mcyE gene expression by the *Microcystis* population, experimental *Daphnia* sp. enrichment had no impact on cyanobacteria biomass (100% of experiments conducted; n=6). In contrast, during fall months when the mcyE gene was not expressed, zooplankton enrichment resulted in significantly reduced ($p < 0.05$) cyanobacteria biomass relative to control treatments in most experiments (80%; n=5). In contrast to mesozooplankton (*Daphnia* sp.), microzooplankton were capable grazing at significant rates (1.2 ± 0.3 d^{-1}) throughout the study, regardless of toxin synthetase gene expression by *Microcystis* or particulate toxin levels. Regarding nutrients, bloom populations transitioned from nutrient replete during spring and early summer to N-limited during late summer when water column N levels were depleted. Specifically, experimental N loading significantly increased *Microcystis* sp. biomass and microcystin concentrations relative to unamended control treatments at this time. Since stormwater run-off entering the lake contained levels of inorganic nitrogen greater than or equal to levels used during experiments (20 µM), this point source of nutrients is a likely promoter of lake toxicity.

Conclusion:

The dominance of *Microcystis* sp. blooms during the summer is linked to both nutrient (N) loading and the suppression of mesozooplankton (but not microzooplankton) grazing which in turn is influenced by cellular toxin synthesis by *Microcystis*.